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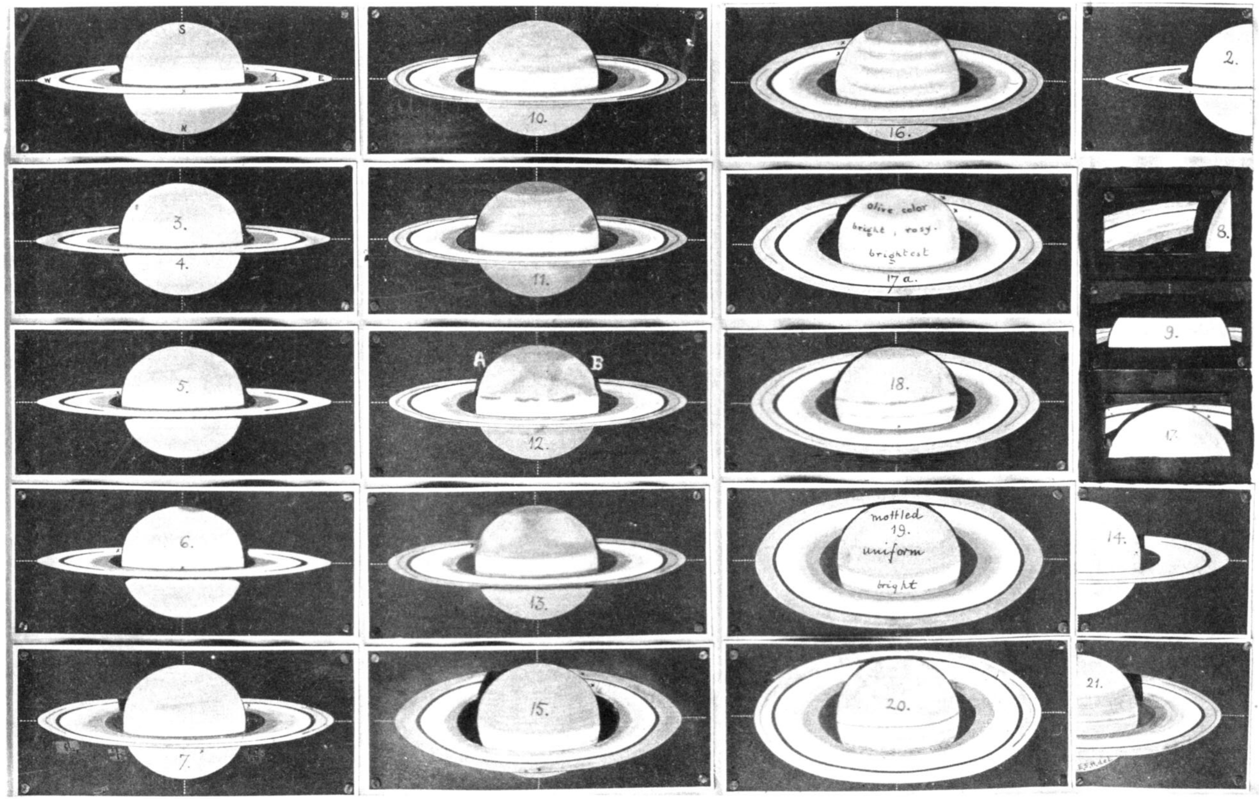

SATURN, 1879-1889.

Edward S. Holden.

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OBSERVATIONS AND DRAWINGS OF *SATURN*, 1879–1889.*

BY EDWARD S. HOLDEN.

During the years 1879–1890, I have made many observations of *Saturn* with the 26-inch equatorial at Washington (1879–80), the 15½-inch at the Washington Observatory (1881–85) and with the 36-inch at the Lick Observatory (1888–90).

For the purpose of recording my notes graphically, I had a set of blank forms engraved on wood, so that the set of six forms would represent (approximately) every degree of inclination of *Saturn's* ring. Each of the accompanying sketches is made on one of these forms; and some distortion of the true figure is introduced in this way. Only that part of each sketch was finished which seemed to have some special significance at the time of observation. The drawings were not intended to be completed pictures, but graphic notes to accompany the written memoranda herewith.

The scale of shading has not been kept constant throughout the eleven years. Two surfaces, equally dark in the accompanying sketches, might have been of quite different brightness when seen on the planet. In the blank forms the engraver inserted some bounding lines, which should have been omitted. Where these are especially misleading I have inserted an x in the foregoing sketches. In spite of these various faults, I have thought that the sketches, and particularly the notes of observation, might be worthy of publication, and I beg to present them to the Society. The planet has been observed on very many occasions of which there is no note here, without seeing any feature calling for special remark.

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* See frontispiece. The Lithographer has been unable to copy my original drawings and I have changed them somewhat by retouching, making them far less satisfactory to myself in the process.

The observations were all made with unusually powerful telescopes. A particular feature in regard to the series is that the sketches do *not* show certain peculiarities of *Saturn*, which have been reported by other observers with smaller telescopes. This may be due to a failure on my own part, but I am inclined to think that it is sometimes, at least, due to the fact that the phenomena of the very complex system of *Saturn* are often too difficult for small instruments. A feature which, by its small size, or by its faintness, is at or near the limit of vision for a small telescope, can often be seen with perfect precision in a larger one. The shortcomings in the present notes cannot, at any rate, be attributed to the instruments employed, since they have all been proved to be of first-class excellence.

Nomenclature.

The drawings are arranged so that the N. pole of *Saturn* is towards the bottom of the figure, and the W. end of the ring is towards the left hand. The outer ring is called A, the main ring B, the dusky ring C. The principal division between A and B is the CASSINI division. The division in ring A (before 1888) is the ENCKE division. No division was seen between rings B and C during these observations.

The steadiness of the atmosphere is noted on a scale of 5 = perfectly steady, 3 = average, 1 = extremely unsteady. Notes added in copying for publication have been put in brackets [ ].

Notes of Observations of Saturn.

1879, Sept. 24, 12^h W. m. t. 26-inch equatorial. Wt. 2.

(*See* Figure 1.) The CASSINI division can be traced no further than it is drawn in the figure. The shadow of the ball on the ring is not black, but ashy-grey; it is not more than $0''.5$ wide at its north end, nor more than $1''.5$ at its south end, and it appears convex to the ball.

1879, Sept. 29. About 11^h W. m. t. 26-inch equatorial. Wt. 4.

(*See* Figure 2). The CASSINI division is as drawn. The division in Ring A is seen at the west end only. Ring B consists of two main parts; the outer part is bright, the inner is grey and much fainter.

1879, Oct. 11, 12^h 15^m W. m. t. 26-inch equatorial. Wt. 5.

(*See* Figure 3). The original drawing is a sketch of the shadows only. Nothing is said about the CASSINI division in front of the ball. Shadows of the ball on the ring are visible on both sides of *Saturn*.

On the west side the shadow is the thinnest possible line as far as the principal division. On both sides the shadow consists of two parts, bounded by nearly straight lines, which meet at an angle as shown. The CASSINI division is seen quite up to the shadows on both sides.

1879, Oct. 16, about $12^h\ 30^m$, W. m. t. 26-inch equatorial. Wt. 2.

(*See* Figure 4.) [To economize space, Figures 3 and 4 are drawn on the same form in the frontispiece. 4 refers to the N. part of the figure only.] The shadow of the ball on the rings is seen on both sides. [No drawing made of this.] The shadow of the ring on the ball is the thinnest possible line, as drawn, thickened at the ends. It looks perfectly straight.

1879, Nov. 3, 12^h W. m. t. 26-inch equatorial. Wt. 2—Eyepiece, 600.

(*See* Figure 5.) *Ball:* the Southern Hemisphere is nearly all an olive-green and dark. All the rest is bright, and no markings are seen, except one streak in the Northern Hemisphere, as in the sketch.

Rings: They are as usual and as drawn.

Shadow of Ball on the Ring: Convex towards the ball [as is usual when the air is not steady] and broken at the principal division. This division, however, is not seen any further than as drawn.

Shadow of Rings on the Ball. Very dark, and the ends widened, as in the figure.

Dusky Ring: The ends of the dusky ring as seen on the ball at the limbs of the planet [above the rings in the figure] are widened, so that the ends on the planet appear broader (north and south) than the fine ends of the dusky ring [outside the ball] which come up to the limbs and meet them.

The whole dusky ring is not so well seen to-night as before, and it appears really fainter.

1879, Nov. 11, 10^h W. m. t. 26-inch equatorial. Wt. 2. Sky hazy.

(*See* Figure 6.) There appears to be a dark patch on the east side of the South Pole, and, possibly, one near to the North Pole, much fainter. The shadow of the ring on the ball is as drawn. The principal division is not seen beyond the points marked.

1880, Aug. 21, $12^h\ 45^m$ to $13^h\ 20^m$, W. m. t. 26-inch equatorial, eyepiece 400, Wt. 3. Sky very hazy.

(Drawing omitted.) The shadow of the ball on the ring is not so black as the spaces within the ansae. The curve of the edge of this shadow appears to be very slightly convex to the ball. The principal division is seen all around. ENCKE'S division in Ring A is seen near the ends of the ring.

1880, Aug. 24. 26-inch equatorial, eyepiece 400. Wt. 4.

(*See* Figure 7.) The principal division is seen all around. The ENCKE'S division is as drawn. It divides Ring A into two parts, whose widths are as 1 to 2, and it is nearer the outer ellipse of Ring A. The south hemisphere of the ball is a warm olive color. The edge of the shadow of the ball on the ring is nearly a straight line, but it is a very little convex to the ball, and it is *black.*

The shadow of the ball on the ring is 2½ times wider at its S. edge than at the N.

The grey shading in Ring B extends from the outer ellipse of the dusky ring to ⅖ of the way to the CASSINI division.

The ends of the dusky ring on the ball [above the rings in the figure] make a little angle where they meet the ends of this ring outside the ball [*i. e.*, the ends on the planet are wider.]

1880, Aug. 26. Time? 26-inch equatorial.

(Drawings omitted.) The shadow of the ball on the ring has about these proportions: west side 3, south side 3, north side 1.

1880, Aug. 27. 26-inch equatorial, Eye-piece 800. Wt. 5. (Drawing omitted.)

The shadow of the ball on the ring is, on the whole, slightly concave to the ball. The appearance of concavity arises from a break in the outline of the shadow at the principal division. The shadow of the ball is seen *on the dusky ring*, and leaves a little sharp corner where this shadow meets the inner ellipse of the dusky ring. The outlines of the principal division are smooth all around. There are no notches at the ends, as drawn by M. TROUVELOT in 1874. There is a trace, and only a trace, of ENCKE'S division on Ring A, ⅓ of the distance from the outer to the inner ellipse of the ring.

Ring B appears to be composed of three rings, distinguished by the difference of shading. The inner one of the three is ⅓ the width of Ring B; the two inner ones together are about 6/10 of this width.

The ends of the dusky ring at the limbs of the planet are wider (north and south) at the limbs than the fine ends of the dusky ring outside the ball which come up to meet them. [This has been previously noted, and *may* be due to the presence of a narrow, dark belt on the planet itself, which is not seen separate from the dusky ring crossing the ball.] At the ends of the dusky rings on the ball there is a distinct "step" at the limb.

It is certain that the outline of the ball cannot be seen through the dusky ring on the west side, but I am almost sure that I see it on the east side.

1880, Sept. 2. 12^h W. m. t. 26 inch equatorial, Eye-piece 400.

(*See* Figure 8.) The sketch is not accurate as to all its dimensions, but it gives the relative shapes and general effect correctly.

1880, Oct. 8. 13^h W. m. t. 26-inch equatorial. Wt. 3. (Drawing omitted.) Sky not perfectly clear.

The principal division is seen up to within about $4''$ of the ball, both in front of and behind the planet. The shadow of the ball on the ring on the west side of the planet is bounded by two straight lines, *a* and *b*. *a* is parallel to a tangent to the S. W. quadrant of the outline of the ball near latitude 45°. *b* makes an angle of 55°–60° with the circumference of the ball near it. *a* and *b* meet at a vertex at the principal division. There is a shade on the ball which borders the shadow of the ball on the west end of the ring. There is also a faint beginning of a shadow of the ball on the ring on the east end of the ring.

1880, Oct. 9. 26-inch equatorial, Eye-piece 800.

(*See* Figure 9.) The shadow of the ball on the ring is seen on both sides of the ball. On the west side, the bounding line of the shadow is a perfectly straight line, and the outer edge of the ring ends in a *fine*, sharp, cusp point; the effect is, perhaps, as if this boundary was slightly, but very slightly, concave to the ball. On the east side of the ball there is a straight, dark, narrow line of shadow also. The CASSINI division is seen all around. The ENCKE division is *well* seen ⅖ of the width of Ring A from its outer edge.

1880, Oct. 10. 26-inch equatorial, Eye-piece 800, Wt. 4.

(*See* Figure 10.) The southern hemisphere of the ball is olive-color. There are two shades or blurs on the ball bordering the shadows of the ball on the ring (which are on both sides).

The shadow of the ball on the ring on the west side is $0''.23$ thick at its north end, and $0''.35$ at its south end. The shadow of the ball on the ring east of the ball is $0''.23$ thick. The dusky ring is suddenly wider as it crosses the ball. The principal division is perfectly smooth all around [no notches in it.] ENCKE's division is seen ⅖ of the width of Ring A from its outer ellipse.

1880, Oct. 11. 26-inch equatorial, Eye-piece 600, Wt. 5.

(*See* Figure 11.) The shadow of the ball on the ring on the west side is *very* narrow at its north end, and a very little wider at its south end. The bounding line is nearly straight, but just perceptibly concave to the ball. The shadow of the ball on the east side is narrower than that on the west, and it appears very slightly convex to the ball. The shadow of the ball on the dusky ring is seen on the east side [only.] I cannot see the limb of the planet through the dusky ring. The principal division is seen up to the shadows on both sides. The dusky ring is suddenly wider as it crosses the ball.

1880, Oct. 12. 26-inch equatorial.

The seeing is too poor for drawing or measures. To-night the shadow of the ball on the ring on the east side looks *very* convex to the ball, while on the preceding side it is considerably concave.

1880, Oct. 15. 26-inch equatorial.

(*See* Figure 12.) Near A and B on the ball are two bright areas. Between them it is darker. Below this dark area it is brighter again. Near the South Pole is a dark olive zone (not so dark as Oct. 11.) The bright knots near A and B are whitish yellow. Just above the equatorial belt the bright space described is less yellow and more inclining to rose-color. The equatorial belt is the brightest part of the ball, and is full of rose-tints. The areas near A and B, and the black shadows just outside them, give to the limb of the ball the straight-line appearance shown in the figure. This phenomenon, which was carefully studied at the telescope, appears to be related to the "square-shouldered" figure of *Saturn* remarked by W. HERSCHEL, in 1805. The south polar cap helps this effect.

1880, Oct. 18. 26-inch equatorial, eyepiece 400, Wt. 2.

(Drawing omitted.) There is hardly any shadow of the ball on the ring on the west side of the planet, if, indeed, there is any. The shadow of the ball on the east side of the ring appears slightly, though certainly convex to the ball. It is quite narrow. The zone of the ball near the South Pole is dark. The central belt is rosy red.

1880, Nov. 7. 26-inch equatorial, eyepiece 400, Wt. 3.

(*See* Figure 13.) The shadow of the ring on the ball, Nov. 7, is north of the ring. The distance between the S. edge of this shadow and the principal division in front of the ball is not more than $0''.3$, and yet I see the white line separating them all the time. I even seem to see the principal division here in front of ball better than usual. The dusky ring on the ball is *much* lighter than the shadow of the ring on the ball. The shadow of ball on ring in the drawing is 1¼ times as wide (east and west) as it should be. The shape is right. Just north of the S. polar dark belt, and at the limb, are two white areas, such as I saw Oct. 15. They produce now something like the square-shouldered aspect, especially on the preceding side, but not so marked as on Oct. 15.

1881, Jan. 12. 26-inch equatorial, eyepieces 400 and 600, *observer* Professor A. HALL.

(*See* Figure 14.) "Division of the ring is sharp and clean. Belts on the ball are very faint. Strong moonlight."

1881, July 29. 15½-inch equatorial of the Washburn Observatory, eyepiece 145. (*See* Figure 15).

1881, Nov. 27, $8^h\ 30^m$ Chicago m. t. 15½-inch equatorial, eyepieces 300, 400. Definition is steady. Moonlight.

(*See* Figure 16).

The width of the dusky ring is half of the distance of the ball to the inner edge of Ring B. The shaded part of B is ⅔ of the width of B. There is a notch in the shadow of the ball on the ring, just at the principal division. The division in Ring A at ⅓ of its width from the outer ellipse, is suspected for over an hour. It is plainer at the preceding end; but I am not absolutely sure of it, after all.

1881, Dec. 7. 15½-inch equatorial, powers 260, 430. Sky hazy.

(Drawing omitted.) The seeing is very steady, through a light haze. The division in Ring A is suspected, as before (Nov. 27), but it is not perfectly certain. The notched shadow of the ball on the ring is certain. The ends of the shadow of the ring on the north hemisphere of the ball are plainly much wider than the middle of this shadow. Both ends are now equally wide, whereas, on Nov. 27, the *east* end appeared to be the wider. The markings on the ball appeared in general as they were on Nov. 27, but the whole sky became cloudy before a drawing could be made or measurements begun.

1882, Sept. 25, $15^h\ 30^m$, Chicago m. t. 15½-inch equatorial. The seeing is good.

(*See* Figure 17.) On the east side of the planet the outer ellipse of the outer ring prolonged towards the west seems almost exactly tangent to the south limb of the ball. On the west side, on the contrary, the ring seems to be moved upwards (south) so that the principal division (prolonged) is almost tangent to the ball, and the outer ellipse of the ring (prolonged) seems to pass to the south of the ball. The illusion continues even where the principal division alone is regarded.

On the east side the principal division (prolonged) plainly intersects the ball. On the west side, however, it is *almost* tangent to it.

A kind of reason for this can be given. On the east side the outer ellipse of Ring *A* comes close to the ball with no black division in between them. It, therefore, seems tangent to it. On the W. side first comes the south limb of the ball, then the shadow of the ball on the ring and beyond and south of this is the Ring A. A very little change in the correct appreciation of the angle terminating the shadow will alter the position of the end of the Ring A greatly. The illusion in regard to the prolongation of the principal division I explain by supposing the eye makes *this* ellipse to be similar to that of the outer ellipse of Ring A, and does not takes its true shape as a guide.

1882, Oct. 3. 15½-inch equatorial, Eye-piece 145.

(*See* Figure 17 *a*.) The general shape of the shadow of the ball on the ring is as drawn, only I have exaggerated the dimensions in order to show the true form more clearly. The south limbs of the ball and of the ring are about tangent. None of the ball is visible north of the ring.

1882, Nov. 8. 15½-inch equatorial, Eye-pieces 145, 240. Wt. 5.

(*See* Figure 18.) The north pole of the ball is just barely visible north of the ring. The principal division is seen all around. The night is very fine. The ENCKE division in Ring A is well seen on the west side as far as the end of the major axis of the dusky ring (outer ellipse.) It is not so well seen on the east side. It divides Ring A into two parts as 2 to 3. [It is, therefore, ⅖ of the way from the outer ellipse of Ring A towards the inner one.] The southern hemisphere of the ball is dark; the region near the south pole is the darkest. There is a dark stripe along the south edge of the bright equatorial belt, and this belt has a narrow stripe along its middle. The shadow of the ball on the ring is seen on both sides of the ball, and the shape is the same on both sides, but the shadow on the west is darker than that on the east.

1883, Nov. 24. 15½-inch equatorial, Eye-piece 145.

(*See* Figure 19.) The ENCKE division is not seen. The CASSINI division is seen all around. The drawing is made to show the shape of the shadow of the ball on the rings. The principal division forms a part of this, and the south limb of the ball of the planet looks like a straight line.

1883, Dec. 2. 15½-inch equatorial, Eye-piece 195.

(*See* Figure 20.) The CASSINI division is seen all around. The ENCKE division is seen at both ends of the ring. The shadow of the ball of the ring is as drawn. It is wider and of a different shape at the west end, as drawn. I did not specially look for (nor see) the shadow of the ball on the Ring C. The south polar region of the ball of the planet is mottled, especially near the shadows. The bright equatorial belt is bounded on the south by a narrow, dark streak some 2″ wide. This is the darkest marking on the ball. South of this is an equally narrow, bright streak, and south of this again is the nearly uniform southern hemisphere. North of the equatorial bright belt is a narrow, dusky belt (1½″ ?), then a narrow, bright belt (1½″ ?), and then a dark band, which is the dusky ring itself (Ring C).

1888, Nov. 5. 36-inch equatorial, Eye-piece 600. Observers, J. M. SCHAEBERLE and E. S. HOLDEN.

(Drawing omitted.) The southern hemisphere is olive-green.

[The south polar region itself is the same color over a region about 0″.5 (north and south) by 2″.2 (east and west). This region is enclosed by a narrow, dark belt (first discovered by J. M. S.), which is a little less than 1″ in width.]

1889, March 22, 8^h 30^m P. s. t. 36-inch equatorial, Eye-piece 2000, Wt. 5. Slight haze. Observers J. M. S. and E. S. H.

(*See* Figure 21.) KEELER's division is seen. J. M. S. sees a new division in Ring B, as drawn. [It was estimated as ¼ of the width of Ring B from its inner ellipse, but the sketch made does not agree with this. The existence of this division has never been confirmed].

Beside the foregoing unpublished observations, the following publications relating to the appearance of the planet have been made by one or more of the astronomers of the Lick Observatory:

Saturn and his Satellites, *Sidereal Messenger* for January, 1889.

Reported Changes in the Rings of Saturn, *Astronomical Journal*, vol. 8, page 180.

The Square-shouldered Aspect of Saturn, *Publications* A. S. P., July 12, 1890.

First Observations of Saturn with the 36-inch Equatorial, *Sidereal Messenger*, 1888, page 79.

The Appearance of Saturn in the 36-inch Telescope, *Ciel et Terre*, January, 1889, page 514.

The Outer Ring of Saturn, *Ciel et Terre*, April, 1889.

represented the general direction of the fainter wisps of nebulosity not quite correctly. To see them at all was an achievement. They are not given in the fine engraving of G. P. Bond for example. The nebula about *c Orionis* is especially good in Schmidt's drawing. The general conclusion from the comparison is that it is *possible* with a six-inch refractor to produce a drawing of the nebula which shall have an astronomical value fairly comparable with that of Mr. Roberts' splendid photograph as reproduced in a paper-print. And, moreover, it is evident that Schmidt's drawing comes very near to giving all that can be seen with such a telescope. When we reflect, however, on the labor required to produce such a drawing and on the fact that its true value can not even be appreciated until it has been compared with the autographic results of photography, and finally that the 205 minutes of exposure must be set against very many hours spent at the telescope in the years 1860–75, the surpassing importance of such representations as those of Mr. Common, of Mr. Roberts, and as our own negatives, becomes manifest.

E. S. H.

THE COMETS OF 1890.

The Comets of 1890 have been:

Comet *a*, discovered by Professor Brooks, at Geneva, New York, March 19.

Comet *b*, discovered by M. J. Coggia, at Marseilles, July 18.

Comet *c*, discovered by W. F. Denning, Esq., at Bristol, July 23.

Comet *d*, (D'Arrest's periodic comet) re-discovered by Mr. E. E. Barnard, at Mt. Hamilton, Oct. 6.

Comet *e*, discovered by Professor T. Zona, at Palermo, Nov. 15.

Comet *f*, discovered by Dr. R. Spitaler, at Vienna, Nov. 16.

CORRECTIONS TO PUBLICATION NO. 13.

Page 2; *for* MATEO CLARK *read* MATEO CLARK*.
" 8; *for* F. W. ZEILE *read* F. W. ZEILE*.

CORRECTION TO PUBLICATION NO. 14.

Page 11; line 3: *for* Washington *read* Washburn.